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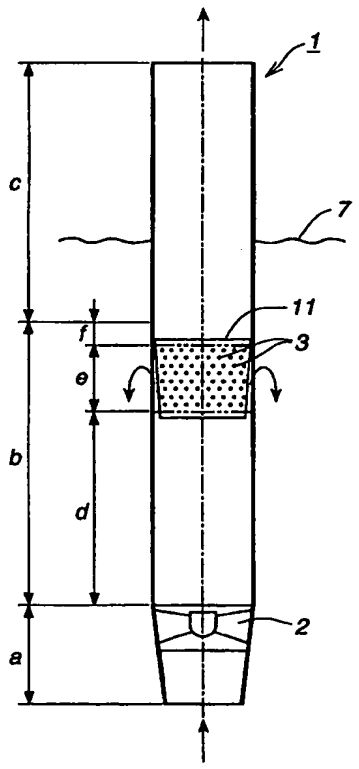
(54) Title: SEPARATOR

(57) Abstract

A separator (1) for separating a liquid from a mixture of liquid and gas. The separator comprises an elongated pipe which is open at both ends. The pipe is divided into a first, a second and a third part (a, b, c). The first part (a) comprises an inlet and an outlet for the mixture and members (2) for achieving rotation in the mixture. The second part, which comprises an inlet and an outlet for the rotating mixture, is divided into a fourth, a fifth, and a sixth part (d, e, f). The fourth and sixth parts (d, f) are designed with tight walls. The fifth part (e) is designed with a substantially circular-cylindrical cross section and with outlet members (3) for outlet of the liquid separated from the mixture. The third part comprises an inlet and an outlet for the remaining part of the mixture.



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Separator

TECHNICAL FIELD

The present invention relates to a separator for separating liquid from a mixture of gas and liquid. The separator is especially suited for separation of water from a steam/water mixture in water-cooled nuclear reactor. The separation of water takes place for the purpose of conducting, as far as possible, steam only to subsequent turbines for the production of electric power. In practice, a plurality of similar separators are arranged for separating the water and carrying away the water to a suitable receiving member.

BACKGROUND ART

One important factor to take into account when designing a separator for separation of liquid from a mixture of gas and liquid in, for example, a nuclear reactor is that the gas, more precisely steam, which leaves the separator is to be as free from the liquid, more precisely water, as possible. Another important factor is that the pressure drop across the separator is to be kept as low as possible. The separation capacity of the separator increases with increased rotation being achieved in the mixture. The higher the rotation achieved in the mixture, the higher the pressure drop across the separator. The two above-mentioned factors, high separation and low pressure drop, thus have a counteracting effect.

SE 373 451 shows (see Figure 1 in the present application) a separator 1 which, divided into parts, exhibits a lower part a, a middle part b and an upper part c. The lower part comprises a blade device 2 for achieving rotation of an incoming two-phase mixture adapted to flow upwards through the separator 1. By setting the incoming two-phase mixture in

rotation by means of the blade device 2, a liquid film is achieved along the inner wall of the separator 1, above all in the middle part b of the separator. By the liquid film, an expulsion pressure is achieved which is necessary for evacuating separated liquid through a primary discharge.

In the middle part b, an outlet member for the primary discharge is arranged, that is, evacuation of the substantial part of the liquid separated from the mixture. The middle part b is designed as an elongated pipe with a narrow circular-cylindrical part and a part which is tapering in the direction of flow, constituting a conical part with a substantially circular cross section. The middle part b is provided, in the conical part, with a plurality of outlet members in the form of openings 3 constituting the member for evacuation of the separated liquid to the outside of the middle part b.

The upper part c is arranged for carrying away the remaining mixture, that is, the gas. The upper part c is designed as a pipe with an upstream, substantially straight circular-cylindrical part and a downstream part which is extended in the direction of flow. The circular-cylindrical part of the upper part is partially arranged inserted into the middle part b with a length which is larger than the extent of the conical part. The upper part c is coaxially arranged in relation to the middle part b.

An outer, substantially circular-cylindrical casing 4 is arranged surrounding the lower part a, the middle part b and the upper part c so as to form an annular gap 5 between the casing 4 and the separator 1. The gap 5 constitutes a return passage for liquid which has been evacuated through the openings 3 in the middle part b.

SE 502 765 shows (see Figure 2 in the present application) a separator 1 of the same type as the one described above, but here the middle part b is provided with openings 3 both in the conical and in the circular-cylindrical part. The openings 3 are arranged also in the circular-cylindrical part to allow a larger opening cross section than what is possible to achieve in practice in the conical part.

The disadvantage of the separators described above is that the expulsion pressure which causes the liquid to be evacuated through the openings is lower the higher up in the conical part the openings are provided. The fact that the expulsion pressure becomes lower in the conical part than in the circular-cylindrical part is due to isobaric surfaces prevailing in the liquid film where the pressure is constant. The pressure distribution in the liquid film is such that the pressure increases with the distance from the centre of the separator. The pressure is thus greatest in that isobaric surface which is arranged nearest the wall of the separator. In the conical part of the separator, however, those isobaric surfaces which are arranged nearest the wall of the separator in the circular-cylindrical part are reduced, whereby the pressure which prevails in the liquid film to drive out the liquid is reduced the higher up in the conical part the two-phase mixture arrives. In other words, the expulsion effect decreases the higher up in the conical part the liquid is transported.

Another disadvantage of the separators described above arises primarily in those cases where the gas flow is very large. In the conical part, a high gas flow may thin out and push aside or separate the liquid film, whereby the openings are exposed and gas may flow out therethrough. This situation is described by the concept "carry under", which indicates how large a proportion of the gas that is evacuated together with the separated liquid through the openings in the wall of the

separator. When the pressure in the liquid film decreases, the carry-under value increases. In the design of a separator it is an aim to have as low a carry-under value as possible, that is, that as little gas as possible is evacuated with the liquid.

A further disadvantage of the known separators is that the openings in the conical part alone and together with the inlet opening into the upper part limit the operating range of the separator by limiting the space for the liquid film. The thickness of the liquid film is a function of the magnitude of the gas and liquid flows which pass through the separator. The liquid film, formed because of the rotation, along the inner wall of the separator may receive a considerable thickness, in which case the inner surface of the liquid film may touch the inlet opening into the upper part of the separator. In case the liquid film touches the inlet opening into the upper part of the separator, the proportion of liquid leaving the separator together with the gas increases dramatically. A concept which describes the proportion of liquid leaving the separator together with the gas is the so-called carry-over value. In the design of a separator, it is an aim to maintain the carry-over value as low as possible.

The present invention relates to a separator which, in relation to known separators, has an improved capacity of separating the liquid.

SUMMARY OF THE INVENTION

The present invention relates to a separator for separating liquid from a mixture comprising gas and liquid. The separator comprises an elongated pipe which is open at both ends and which is divided into a first, lower part, a second, middle part, and a third, upper part.

The lower part comprises an inlet for the mixture and members for achieving rotation in the mixture and an outlet for the rotating mixture. The rotation is achieved with a conventional blade device.

The middle part is provided with an inlet for the rotating mixture and is designed for separation of the liquid from the mixture. The middle part is divided into a fourth, a fifth and a sixth part. The fourth and sixth parts are designed with tight walls whereas the fifth part is designed with outlet members in the form of openings for evacuation of the separated liquid. At least the fifth part is designed as a substantially circular-cylindrical part. The sixth part is intended for outlet of the remaining mixture.

The upper part is intended for inlet and outlet of the remaining mixture, that is, the gas.

It is an advantage to design the separator with openings only in a straight circular-cylindrical part by creating a uniform pressure difference across the outlet cross section, that is, across the openings through which the separated liquid is evacuated. More precisely, an expulsion pressure is created which is equally great at each opening for evacuation of liquid. The uniform pressure difference across the outlet cross section implies that the expulsion effect increases in comparison with the prior art. This more efficient utilization of the outlet cross section also allows the level of the above-defined carry-over and carry-under values, respectively, to be kept low.

Another advantage of designing the separator with openings only in a circular-cylindrical part is that the size, the location, and the extension of the openings may be adapted to current gas and liquid flows.

The upper part of the separator substantially constitutes a transport distance for the remaining mixture and has no primary influence on the separation capacity of the separator and may, therefore, be given an arbitrary design. The upper part may, for example, be straight circular-cylindrical or conical.

An advantage of designing the whole separator pipe with a substantially straight circular-cylindrical shape is that it is considerably more simple to manufacture such a separator than the known separators since no conical part need be included, still less a conical part with openings. The conical part is geometrically limited, in which case it is more difficult to calculate how the openings are to be arranged in this surface in an optimum way in comparison with the arrangement of such openings in a part which is designed as a straight cylinder with a substantially circular cross section.

The amount of liquid in the mixture remaining after the separation may be further minimized by arranging a separate upper part extending into the middle part in such a way that its inlet is arranged downstream of the evacuation openings in the middle part. By arranging the inlet into the upper part downstream of the outlet members, it is ensured that the thickness of the liquid film is greatly reduced such that the inner surface of the liquid film does not risk getting into contact with the inlet into the upper part.

Still another advantage of designing the middle part as a substantially straight circular-cylindrical part is that the cross section of the outlet in the upper part increases. The enlarged gas outflow cross section implies that the pressure drop across the separator is reduced in comparison with the known separators described under the background art.

The operating range of the separator is suitably chosen such that it is arranged in an optimum way between the boundary curves which may be calculated for the carry-over and carry-under values, respectively. This is possible by the size and location of the openings in the circular-cylindrical part being adapted and optimized for the current gas and liquid flows.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be explained in greater detail with reference to the accompanying drawings.

Figure 1 shows a separator with outlet members in the form of openings in a conical part described under the background art.

Figure 2 shows an alternative separator with outlet members in the form of openings both in a conical part and in a circular-cylindrical part. Also this separator is described under the background art.

Figure 3 shows in a longitudinal cross section a separator according to the invention, which comprises a substantially straight circular-cylindrical pipe which is open at both ends. Only one circular-cylindrical part is provided with outlet members in the form of openings.

Figure 4 shows an alternative embodiment of a separator with a cross section increasing in the direction of flow. A dash-lined contour indicates an alternative embodiment wherein the upper part is designed with a cross section which decreases in the direction of flow.

Figure 5 shows an embodiment of a separator according to the invention which comprises an upper part arranged inserted

into a circular-cylindrical middle part where the upper part is designed with a cross section increasing in the direction of flow.

Figure 6 shows an embodiment of a separator according to the invention which, in a middle part, comprises a conical part and an upper part arranged inserted thereinto, wherein the upper part is designed with a cross section increasing in the direction of flow. A dash-lined contour indicates an alternative embodiment where the upper part is designed as a straight circular-cylindrical pipe.

Figure 7 shows an embodiment of a separator according to the invention wherein a substantially circular-cylindrical casing is arranged to surround the separator and, together with this, to form an annular gap.

Figure 8 shows, in a view from above, an embodiment wherein several groups of separators are arranged and wherein they are arranged in groups surrounded by a casing such that each casing surrounds a plurality of separators.

Figure 9 shows in detail an embodiment of a scraper ring shown in Figure 7.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 3 shows a separator 1 which comprises an elongated pipe which is open at both ends. The separator 1 is divided into a first, lower part a, a second, middle part b, and a third, upper part c.

The lower part a comprises an inlet for a mixture of gas and liquid. The lower part a further comprises a blade device 2 which is adapted to set the incoming mixture in a rotary or turning motion. Through the influence of a centrifugal force

in the rotating mixture, the liquid in the two-phase mixture will make contact with the inside of substantially the wall of the middle part b and will form a distinct, well coherent liquid film.

The middle part b comprises an inlet for the rotating mixture, outlet members for evacuation of the separated liquid and an outlet for the remaining mixture.

The middle part b is divided into a fourth part d, a fifth part c and a sixth part d. The fifth part e is designed for separation of the liquid from the mixture. For this purpose, the fifth part e comprises a substantially straight circular-cylindrical part which is provided with outlet members in the form of a plurality of openings 3 through which the separated liquid is evacuated. The wall of the fifth part e with the openings 3 is dimensioned in dependence on the type of plant, for example a nuclear reactor, in which it is to be used. This implies, for example, that the middle part b is provided with openings 3 of a smaller total area for plants with a large gas flow and with openings 3 of a larger total area for plants with a large liquid flow.

The fourth part d and the sixth part f are designed with tight walls for the purpose of not evacuating any separated liquid.

The upper part c is intended for inlets and outlets of the remaining mixture, that is, the gas. In Figure 3, both the upper part c and the middle part b are integrated and designed in the same pipe part, provided with a substantially straight circular-cylindrical shape.

In Figures 3, 4 and 7, the liquid level outside the separator 1 is indicated by the reference numeral 7. The primary discharge of the liquid separated in the middle part b is thus

discharged at a level which is arranged below the liquid surface 7. This implies that the carry-under level is kept down since the outflowing liquid is not allowed to come into contact with the gas over the liquid surface, nor stirs the surface such that gas bubbles are formed therein.

Figure 5 shows a separator 1 which comprises a separate upper part c which is arranged inserted into the middle part b. By arranging the upper part c for outlet of the remaining mixture inserted into the middle part b, it is further ensured that the liquid flowing along the inner wall of the separator 1 is protected from the influence of the remaining mixture flow upwards through the separator. At least a part of the liquid film which is adapted to cover the openings 3 will continue to flow upwards, with the aid of the remaining mixture, along the inner wall in at least the fifth part e. The inlet of the upper part c is arranged at a level which is arranged downstream of the wall portion with the openings 3. By arranging a separate outlet for the remaining mixture downstream of the openings 3, the remaining mixture, that is the gas, may be removed from the separator 1 without the liquid film, which is greatly reduced because of the primary outlet, being evacuated therewith. This implies that the liquid is prevented from remoistening the gas, which, in turn, causes the carry-over value to be further kept low.

Figure 6 shows an embodiment of the separator 1 in Figure 5, wherein the middle part b is partially conical. More particularly, the sixth part f is conical. The upper part c is arranged inserted into the conical middle part b and designed with a cross section increasing in the direction of flow. An additional alternative embodiment of the upper part c is indicated by a dash-lined contour, more particularly an upper part c with a circular-cylindrical shape.

Figure 7 shows an alternative embodiment of a separator 1, wherein a casing 4 is adapted to surround at least the fifth part e. Between the casing 4 and the fifth part e, an annular gap 5 is formed for return passage of the liquid separated through the openings 3. The arrangement of an outer casing 4 in this way permits a reduced risk of adjacently located separators 1 disturbing the evacuation of liquid from the separator 1 in question. It is also possible to allow the casing 4 to surround a group of a plurality of separators 1, as shown in Figure 8. In this case, the casing 4 is given a cross section with an arbitrary shape for adaptation to the group of separators 1. Figure 8 shows a plurality of groups, wherein each group comprises five separators 1 arranged in, for example, the upper part of a nuclear reactor 10.

Figure 7 further shows that the upper part c of the separator 1 is provided with so-called scraper rings 6. The scraper rings 6 are arranged for secondary separation of liquid which passes with the gas past the primary separation, that is, the openings 3. The scraper rings 6, which are shown in more detail in Figure 9, are thus adapted to scrape off and evacuate the liquid which is separated from the mixture downstream of the openings 3. The scraper rings 6 are of a conventional type and adapted to reduce the amount of liquid accompanying the gas out, that is, to keep down the carry-over value defined under the background art.

Figure 3 shows a separating member 11 in the form of a truncated cone. The separating member 11 is arranged in the middle part b and radially inside the fifth part e. The separating member 11 is arranged such that it has a cross-section area increasing in the direction of flow. The difference between the inner cross-section area of the separator 1 and the outer cross-section area of the separating member 11 at the upstream edge of the separating member 11 corresponds at least to the cross section area of the

liquid film which flows along the inner wall of the middle part b. The object of the separating member 11 is to achieve an additionally improved separation of the liquid by preventing the liquid film from flowing upwards along the inner wall of the separator so far that it risks becoming unstable and collapsing. The separating member 11 has an extent in the axial direction of the separator which substantially corresponds to the axial extent of the fifth part e. The downstream edge of the separating member 11 is tightly connected to the inner wall of the separator 1. In one embodiment (not shown), the separating member 11 has the shape of a pipe with an arbitrary cross section.

Figure 7 shows a separating member 12 in the form of an inner shoulder arranged downstream of the openings 3. The separating member 12 is adapted to extend from the inner wall of the separator 1 and radially inwards along a distance which at least corresponds to the thickness of the liquid film in this part of the separator 1. The object of the separating member 12 is the same as that of the separating member 11 according to Figure 3. In one embodiment (not shown), the separating member 12 has a tubular part connected to the shoulder and extending in an upstream direction. The tubular part has an arbitrary cross section.

It is self-evident that the different embodiments of middle parts b, upper parts c, casings 4, scraper rings 6 and separating members 11, 12 shown may be combined in a plurality of different ways (not shown).

CLAIMS

1. A separator (1) for separating a liquid from a mixture of liquid and gas, wherein the separator comprises an elongated pipe which is open at both ends, the pipe being divided into a first part (a), a second part (b) and a third part (c), the first part (a) comprising an inlet and an outlet for the mixture and members (2) for achieving rotation in the mixture, the second part comprising an inlet and an outlet for the rotating mixture and outlet members (3) for outlet of the liquid separated from the mixture, the third part comprising an inlet and an outlet for the remaining part of the mixture, **characterized** in that the second part (b) is divided into a fourth part (d), a fifth part (e) and a sixth part (f), the fourth and sixth parts (d, f) being designed with tight walls, the fifth part (e) being designed with a substantially circular-cylindrical cross section, and in that the outlet members (3) are arranged in the fifth part (e).

2. A separator (1) according to claim 1, **characterized** in that the second part (b) and the third part (c) are integrated and designed as a substantially straight circular cylinder.

3. A separator (1) according to claim 1, **characterized** in that the third part (c) is designed as a separate part arranged partially inserted into the second part (b) such that the inlet into the third part (c) is arranged completely or partially downstream of the fifth part (e).

4. A separator (1) according to any of the preceding claims, **characterized** in that it is surrounded by a casing (4) in such a way that between the casing (4) and the fifth part (e), an annular gap (5) is formed.

5. A separator (1) according to any of the preceding claims, **characterized** in that a group comprising a plurality of separators (1) is arranged surrounded by a casing (4).

6. A separator (1) according to any of the preceding claims, **characterized** in that the third part (c) is designed as a straight circular cylinder or with a cross section which increases or decreases in the direction of flow.

7. A separator (1) according to any of the preceding claims, **characterized** in that the third part (c) is designed with at least one scraper ring (6).

8. A separator (1) according to any of the preceding claims, **characterized** in that, radially inside the outlet members (3), a separating member (11) is arranged in the form of a pipe with an arbitrary cross section which, at a downstream edge, connects tightly to the inner wall of the separator (1).

9. A separator (1) according to claim 8, **characterized** in that the separating member is designed as a truncated cone with a cross section area increasing in the direction of flow.

10. A separator (1) according to any of claims 1-7, **characterized** in that, downstream of the outlet members (3), a separating member (12) is arranged in the form of a shoulder extending from the wall of the separator (1) and radially inwards.

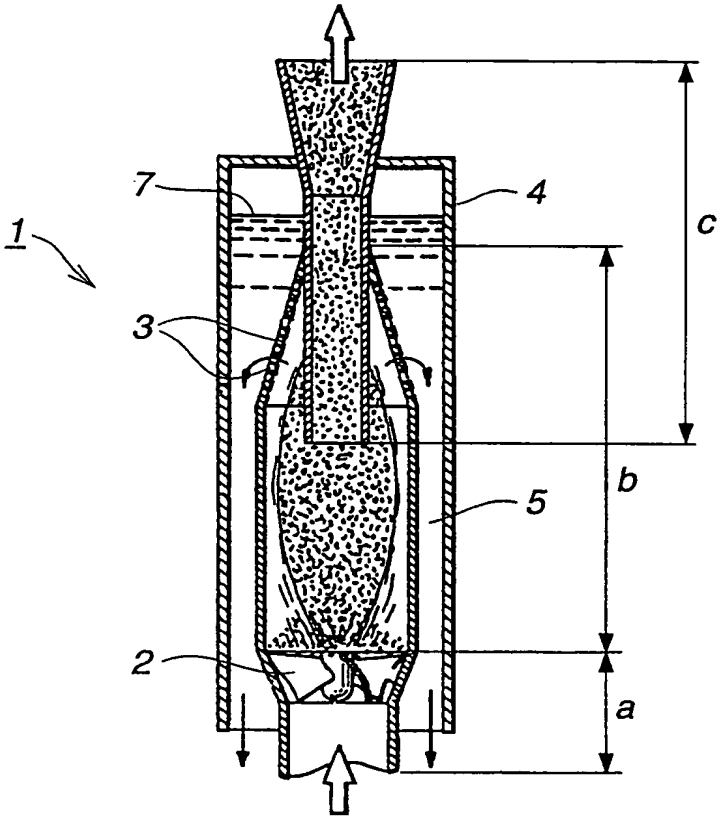

Fig. 1
(Prior art)

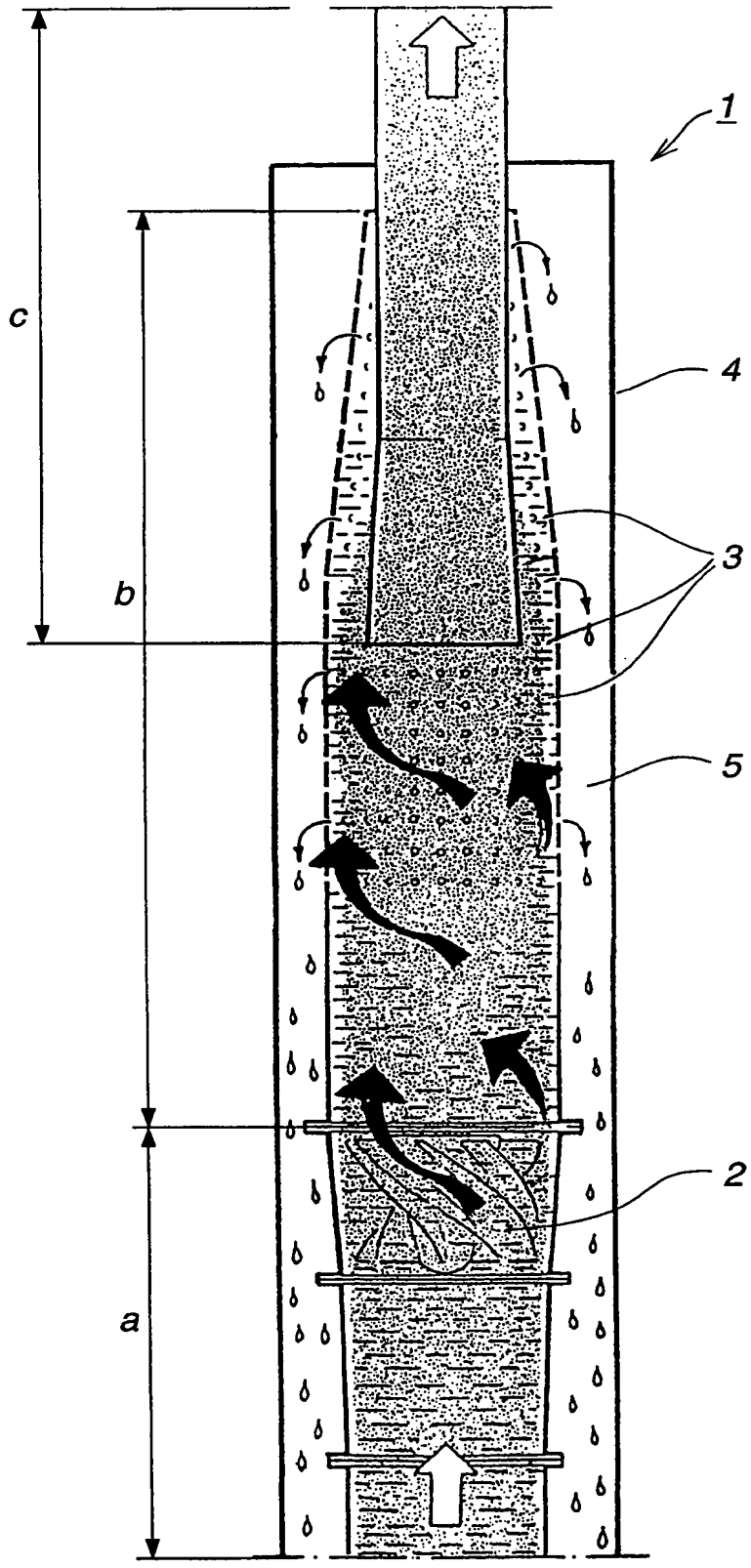

Fig. 2
(Prior art)

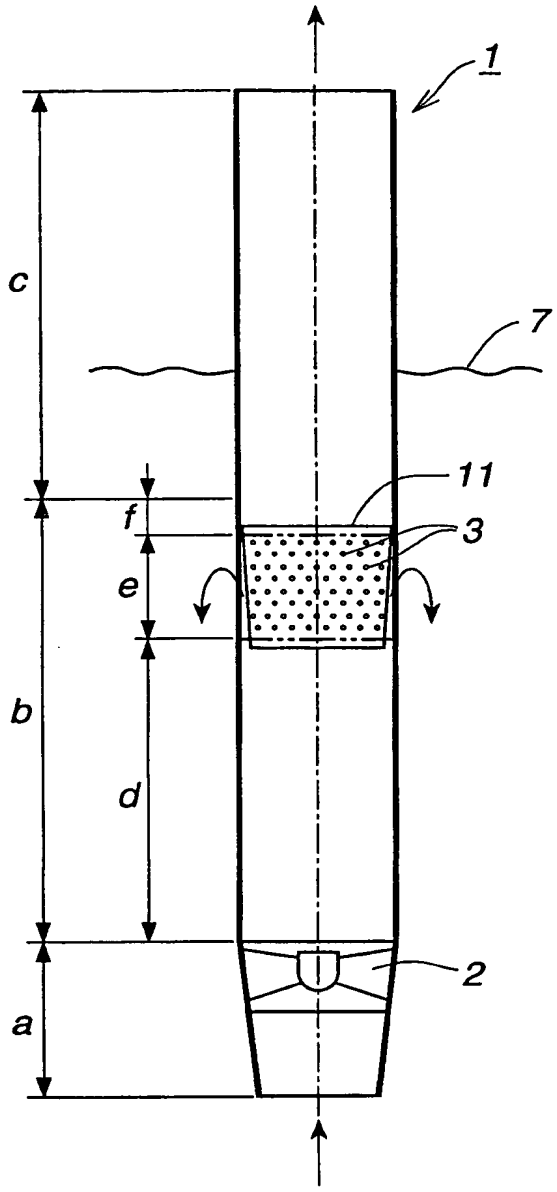

Fig. 3

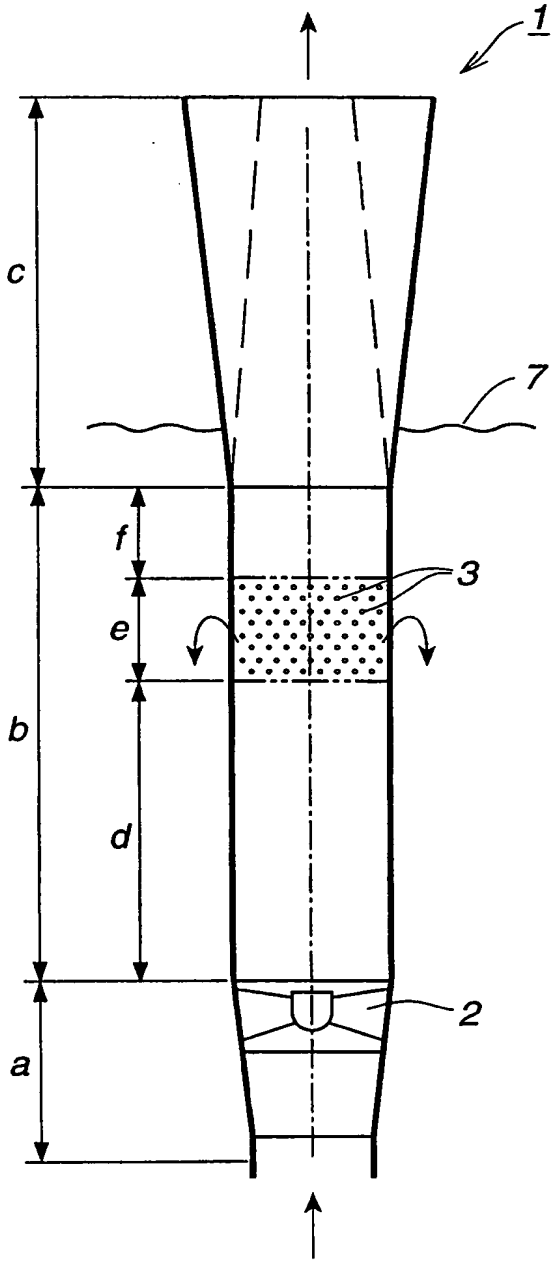

Fig. 4

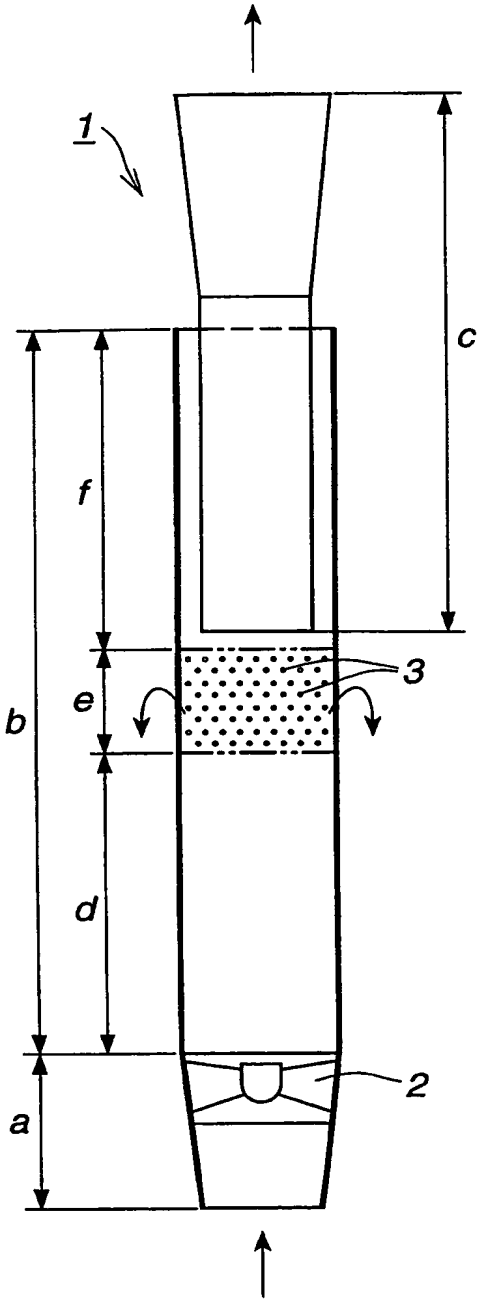

Fig. 5

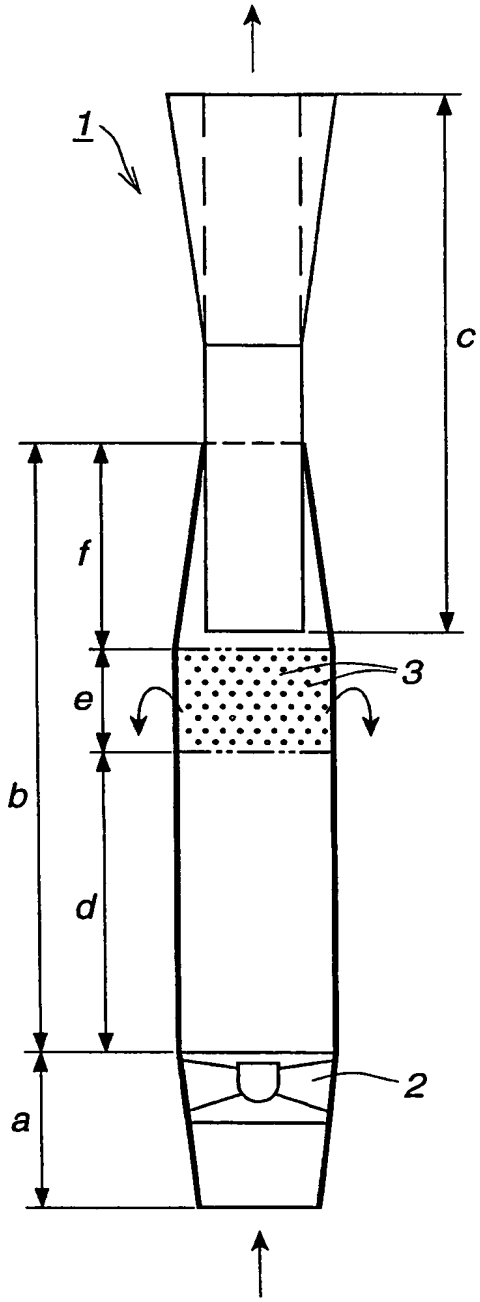

Fig. 6

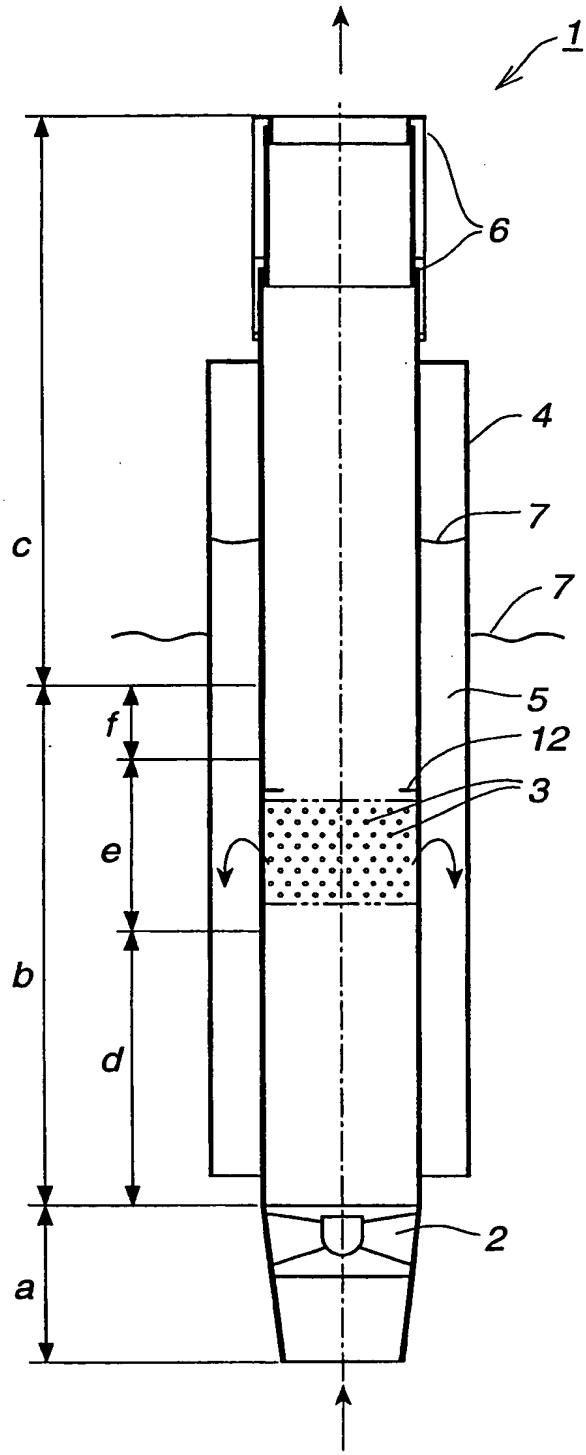

Fig. 7

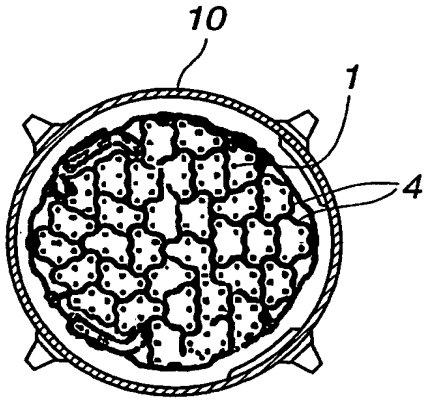

FIG. 8

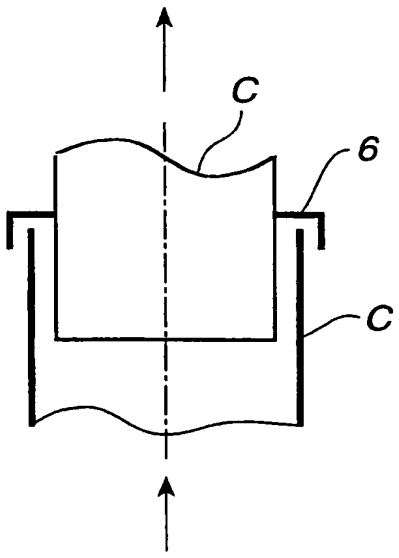

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 98/00687

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: B01D 45/14, B04C 3/06 // G21C 015/16
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: B01D, B04C, G21C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

QUESTEL; EDOC, WPIL

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4602925 A (KENNETH.L.HUFFMAN), 29 June 1986 (29.06.86), column 1, line 6 - line 12; column 5, line 43 - line 56, figures 2,4	1-10
A	EP 0410624 A1 (GENERAL ELECTRIC COMPANY), 30 January 1991 (30.01.91), column 10, line 47 - column 11, line 1, figures 1,2, claim 1	1-10
A	EP 0203896 A3 (ANSALDO S.P.A.), 3 December 1986 (03.12.86), page 4, line 28 - page 5, line 27, figures 1,2	1-10

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
8 July 1998	13 -07- 1998
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Bengt Christensson Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 98/00687

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